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DEMONSTRATION OF AN ALCOHOL FUEL PLANT AND STRAW BOILER

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MONTANA DEPARTMENT of NATURAL RESOURCES and CONSERVATION

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Demonstration of an alcohol fuel plant a
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DEMONSTRATION OF AN ALCOHOL FUEL PLANT AND STRAW BOILER

Prepared by

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June, 1983

Prepared for

Montana Department of Natural Resources and Conservation
32 South Ewing, Helena, Montana 59620
Renewable Energy and Conservation Program
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A. PROJECT DESCRIPTION

The project consists of a farm based fuel alcohol plant capable of producing 20 gallons alcohol per hour from barley or wheat as the feedstock. Fuel alcohol produced is mixed with gasoline to form gasohol and is used in farm vehicles or sold to fuel distributors. The distillers grain produced by the plant is used for cattle feed.

1. Straw Fired Boiler

Steam required for the alcohol plant process is produced by a farm-built straw fired boiler system shown in the attached photographs and drawings. During harvesting of the wheat or barley, the straw is left in windrows by the harvester combine and is baled into large 700 lb round bales. The bales are then hauled and stacked adjacent to the alcohol plant.

There are many other methods of gathering and storing straw such as large "breadloaf" stack wagons or smaller conventional size bales. The best method depends upon the particular farm and existing machinery available. In our case, the use of round bales was very fuel efficient with no hand labor required.

The straw bales to be burned in the boiler system are chopped to 2 inch maximum straw length and elevated into the V-bottom chopped straw bin. The use of chopped straw allows the straw to be augered at a steady rate from the straw bin into the straw combustion chamber and it also lets the straw burn in suspension for complete combustion without smoke.

The straw combustion chamber is lined with a high temperature castable refractory cement to protect the steel sides and reduce heat loss. A cleanout door on the side is used to remove the ashes. The hot gases from combustion of the straw are piped in a 14 inch refractory lined pipe to produce steam in a conventional 50 H.P. (1,500,000BTU/Hour) steam boiler.

Combustion tests on the boiler system have shown that the straw produces approximately 7,000 BTU heat per pound burned. Combustion efficiency of the boiler system was found to be 80% at full capacity which is comparable to conventional gas fired boilers. Further testing is necessary to determine the average efficiency at reduced firing rate and considering startup losses, etc.

2. Alcohol Plant

A simplified schematic of the basic alcohol plant is attached. Rather than pruchase a packaged factory built plant, most of the equipment was designed and/or built on the farm.

A brief description of the plant operation is as follows: the cracked grain is mixed with water and enzymes in the cooker-fermentor tanks and steam is injected to cook the mash. Yeast is added to convert the sugar to a 8-10% alcohol content beer. After the solids (distillers grain) are separated out, the beer is distilled in the distillation columns to 190 proof alcohol. Approximately 1.9 - 2.0 gallons of alcohol is produced per bushel of grain.

Several innovative features were used on the plant not found on most farm alcohol plants:

a. To reduce water consumption, the cooling water used by the plant is recirculated through a cooling water pit located near the building. The cooling water is pumped through the wall of the double wall cooker tanks to eliminate any coils inside the tanks and allow for easier cleaning of the tanks.

b. The cooker tanks are galvanized steel and coated with expoxy paint to prevent corrosion.

c. A mixing pump is used rather than paddle type agitators for ease of cleaning of the tanks.

d. A preheat tank is used to recover heat from the process and save fuel.

e. The beer feed and reflux pumps are positive displacement type pumps to maintain even flow rates to the still columns.

f. A screw press manufactured by the Somat Co. is used for a solids separator which is more efficient in removing the distillers grain than vibrating screen type separators.

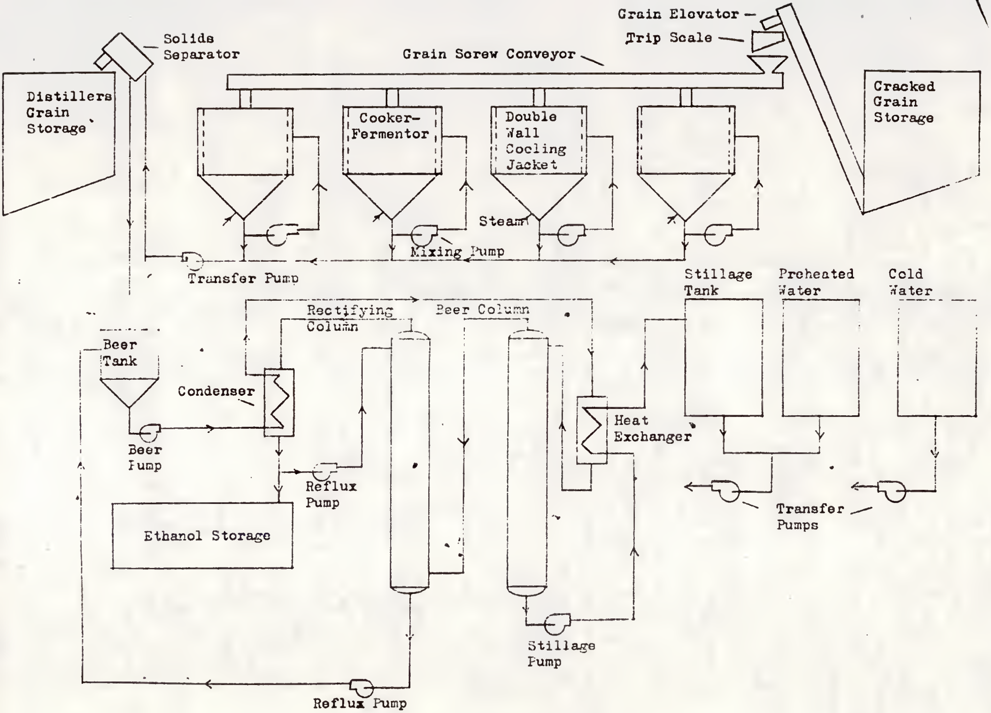
3. Dehydrator

The project also includes an alcohol dehydrator which upgrades the alcohol from 185 or 190 proof to 200 proof alcohol which can be mixed with gasoline to form gasohol. The storage tanks, meters and piping are arranged so that the system is capable of upgrading alcohol from other farm plants in the area.

Dehydration of the ethanol is accomplished by pumping the ethanol through a bed full of molecular sieve beads which adsorb the water from the ethanol. After the molecular sieve beads are staurated they are regenerated by heat which drives the water off as steam.

The design of the dehydrator which was built on the farm is shown in the construction drawings. The dehydrator column is constructed with a 30 inch diameter by 13 foot high steel shell with thirty-six (36) 3 inch diameter pipes inside the shell. The 3 inch diameter pipes hold the molecular sieve beads through which the ethanol is pumped during the adsorption cycle.

To regenerate the dehydrator, hot flue gases from the straw fired steam boiler are passed over the outside of the pipes. This system utilizes waste heat which would normally just pass up the boiler stack.



ETHANOL PLANT PROCESS SCHEMATIC

C. ENERGY SAVINGS AND PAYBACK

Although the plant has not operated a long period of time, the annual alcohol production at 50% operating time will be approximately 73,000 gallons ethanol. At this point in time the overall net positive energy savings for the plant is about 29,000 BTU/gallon ethanol as calculated in the original grant application. Actual payback on the entire alcohol plant cannot be obtained without further operating experience.

For those interested in using straw as a fuel, the energy savings and payback for the straw fired boiler system can be calculated as follows:

1. Annual Straw Consumption:

Actual plant steam consumption indicates approximately 35,000 BTU is required to process 1 gallon alcohol.

Annual process heat = (35,000 BTU/gallon) X (73,000 gallons alcohol/year = 2555 Million BTU/year.

Heat input to boiler = (2555 Million BTU/year) ÷ 70% Average Boiler Efficiency = 3650 Million BTU/year Energy Savings From Using Straw As Fuel

Annual Straw Used = (3650 Million BTU/year) ÷ 7000 BTU/lb. straw = .52 Million lbs./year = 260 tons straw/year

2. Straw Fuel Cost:

Actual total cost to bale and gather the straw including labor, fuel, and machinery used is about $15/ton.

ANNUAL straw cost - ($15/ton) X (260 tons) = $3,900/year

3. Conventional Fuel Cost

If propane were used instead of straw to fuel the boiler at $.80/gallon the annual cost would be:

Propane Cost = (3650 Million BTU/year) X $8.00/Million BTU = $29,200/year

Net fuel cost savings = $29,200 - $3,900 = $25,300/year

4. Payback

The cost of the straw boiler system was about $30,000 more than a conventional boiler system.

Payback = $30,000 added cost ÷ $25,300 savings = 1.2 Year Payback

D. REVIEW OF CONSTRUCTION PHASE

As with most projects, the construction and startup phase of the project took much longer than expected. The original plan was to purchase a factory fabricated alcohol plant and boiler system, but after review of available systems we decided to design and build most of the equipment ourselves. Although construction of home-built equipment takes longer, we recommend this as a means of keeping project costs to a reasonable amount. It seems that most alternative energy equipment including alcohol plants are overpriced and the manufacturers do not completely guarantee the equipment anyway.

Most construction delays in this project were due to late deliveries of materials. Some of the controls, fans and pumps took 4 months to receive from time of ordering.

The plant building was an existing building which was remodeled and added on. As it turned out a new building with more space could have been built for the same amount of money, because of all the labor and changes required to adapt the building to fit the equipment.

During construction several changes in the design of the boiler system and alcohol plant were made. (1) The cracked grain bin was located outside to leave more room inside the building. (2) The double walls of the cooker tanks had to be reinforced to prevent buckling of the inside tank wall. (3) The rotating bridge breaker inside the chopped straw bin was reduced in size to reduce the motor load. (4) A steam pressure reducing valve was added to maintain a constant steam supply pressure.

Charles Bronec Receives Tentative $37,000 Grant

A proposed farm-scale fuel alcohol plant near Geraldine has received a tentative grant of $37,000 from the Montana department of natural resources and conservation's renewable energy program.

Under the grant, Charles Bronec of Geraldine plans to install a plant capable of producing 73,000 gallons per year of 190 proof alcohol fuel and high protein stillage feed. The plant will use grain as a feedstock for the ethanol and will incorporate a waste fuel boiler in the production process.

Bronec has also received funding for this project from the food and fuels program of the Montana department of agriculture.

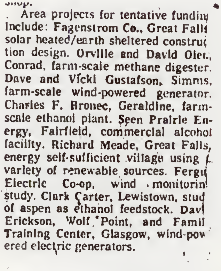
John Orndorff, chief of the renewable energy bureau of DNRC's energy division, said the agency has approved 69 of the record 175 proposals it received for alternate energy projects during fiscal year 1981.

This year's projects will fall into two categories, Orndorff said, those approved for definite funding and those approved for tentative funding. Because of increased coal production and the rise in coal prices, the amount of money in the renewable energy program's account, which is based on 2.5 percent of the state's coal severance tax, is $2.5 million greater than the amount that was actually made available to the program at the beginning of the 1980-81 biennium.

Program officials will ask the state legislature in January to formally make the remaining renewable energy program funds available for grants. Definite projects will be funded through the almost $500,000 now directly available; tentative projects would be funded through remaining program funds.

Other renewable energy projects across the state include a series of wind-powered electric generators for Livingston's sewage treatment plant; a fuel alcohol plant under construction in Amsterdam; an innovative solar heated/earth sheltered construction design; and several residential sized hydroelectric systems across the state.

Fort Benton River Press



shop.

Area projects for tentative fundin include: Fagenstrom Co., Great Fall solar heated/earth sheltered construction design. Orville and David Olen, Conrad, farm-scale methane digester. Dave and Vicki Gustafson, Simms, farm-scale wind-powered generator. Charles F. Bronec, Geraldine, farm-scale ethanol plant. Seen Prairie Energy, Fairfield, commercial alcohol facility. Richard Meade, Great Falls, energy self-sufficient village using variety of renewable sources. Fergu Electric Co-op, wind monitorin study. Clark Carter, Lewistown, stud of aspen as ethanol feedstock. Dav Erickson, Wolf Point, and Famil Training Center, Glasgow, wind-powered electric generators.

Great Falls Tribune

SECTION F.

PROJECT COST

	DNRC	OTHER SOURCES	TOTAL
1. SALARIES AND BENEFITS			
A. Labor to Construct Boiler and Dehydrator	18,000	7,000	25,000
B. Labor to Construct Basic Ethanol Plant	-	14,000	14,000
C. Consulting Engineering Design By Larry Bronec	6,000	3,000	9,000
Subtotals	$24,000	$24,000	$48,000
2. OPERATING EXPENSES			
A. Contracted Services			
a. Water Well Drilling and Pump	-	3,200	3,200
b. Water Testing	-	100	100
c. Pipe Trenching	-	400	400
d. Printing, Typing, Blueprinting	-	400	400
e. Insurance	-	200	200
f. Interest on Construction Loan	-	4,500	4,500
g. D-7 Dozer Use on Cooling Water Pit	-	3,000	3,000
Subtotals	-	$11,800	$11,800
B. Supplies			
a. Bookkeeping, Drafting & Office Supplies	-	200	200
b. Reference Books - Alcohol Production	-	100	100
Subtotals	-	$ 300	$ 300
C. Communications			
a. Telephone Calls	-	800	800
b. Postage & Mailing	-	100	100
Subtotals	-	$ 900	$ 900
D. Travel and Transportation			
a. Expenses	-	2,000	2,000
Subtotals	-	$ 2,000	$ 2,000
E. Rent	-	-	-
F. Straw Fuel Gathering (140 Tons)			
a. Tractor Use	-	1,700	1,700
b. Baler Parts and Twine	-	300	300
c. Fuel	-	100	100
d. Plastic Stack Covering	-	600	600
Subtotals	-	$ 2,700	$ 2,700
3. EQUIPMENT			
A. Building Remodel and Addition			
a. Materials	-	8,400	8,400
Subtotals	-	$ 8,400	$ 8,400
B. Farm Built Basic Alcohol Plant			
a. 4-2500 Gallon Cooker-Fermenter Tanks	-	8,800	8,800
b. Water Storage Tanks	-	1,000	1,000
c. Somat Co. Solids Separator	-	4,300	4,300
d. Distillation Columns	-	15,000	15,000
e. Pumps and Motors	-	3,600	3,600
f. Controls	-	2,100	2,100
g. Cracked Grain Mill	-	3,900	3,900
h. Water Meters	-	400	400
i. Unit Heater	-	200	200
j. Electrical Materials	-	2,100	2,100
k. Grain Bins	-	1,400	1,400
l. Grain Augers	-	1,600	1,600
m. Pipe, Valves and Fittings	-	2,800	2,800

		DNRC	Sources	Total
n.	Beer Tank	-	200	200
o.	Insulation	-	800	800
p.	Miscellaneous Items	-	400	400
q.	Equipment Shipping	-	1,800	1,800
	Subtotals	-	$50,400	$50,400
C.	Straw Fired Boiler System			
a.	KISCO 50 H.P. Watertube Steam Boiler	8,000	-	8,000
b.	Induced Draft Fan and Motor	2,100	-	2,100
c.	Straw Processing Equipment (Straw Chopper and Round Bale)	-	5,000	5,000
d.	Combustion Chamber Refractory	2,100	-	2,100
e.	Combustion Chamber Steel	1,100	-	1,100
f.	Warm-Up Burner	500	-	500
g.	Straw Auger & Bridge Breaker Drive	1,200	-	1,200
h.	Controls and Instruments	800	-	800
i.	Boiler System Pipe, Valves & Fittings	1,400	-	1,400
j.	Straw Hopper Steel	2,900	-	2,900
k.	Combustion Air Fan and Motor	400	-	400
l.	Flue Gas Pipe and Stack	400	-	400
m.	Feedwater Pump	700	-	700
n.	Boiler Water Treatment System and Chemical Pump	1,200	-	1,200
o.	Electrical Materials	900	-	900
p.	Insulation	200	-	200
q.	Boiler Feedwater Preheat Tank	1,000	-	1,000
r.	Equipment Shipping	400	-	400
s.	Paint, Bolts, Welding, Misc. Materials	200	-	200
	Subtotals	$25,500	$ 5,000*	$30,500
D.	200 Proof Dehydrator System			
a.	2 - 10,000 Gallon Ethanol Tanks	2,700	-	2,700
b.	Pipe, Valves, and Fittings	2,100	-	2,100
c.	Ethanol Meters	1,200	-	1,200
d.	Molecular Sieve Beads	2,800	-	2,800
e.	Ethanol Pumps and Motors	2,500	-	2,500
f.	Ethanol Tank Fuel Loading Equipment	1,400	-	1,400
g.	Flue Gas Pipe	400	-	400
h.	Insulation	800	-	800
i.	Electrical Materials	2,100	-	2,100
j.	Controls and Instruments	2,600	-	2,600
k.	Equipment Shipping	400	-	400
l.	Paint, Bolts, Welding, Misc. Materials	500	-	500
m.	Dehydrator Steel	1,000	-	1,000
	Subtotals	$20,500	-	$20,500
	PROJECT TOTALS	$70,000	$105,500	$175,500

*Cost includes used straw chopper and baler purchased. Cost will increase to $13,000 when new chopper is purchased.

Funding From other sources includes $20,000 loan from Montana Dept. of Agriculture. Figures Rounded to nearest $100.00.

ENT TO FINAL REPORT
ATOR AND STRAW BOILER
S F. BRONEC, PRESIDENT
23 GERALDINE,MT
EMENT: 437-811

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File

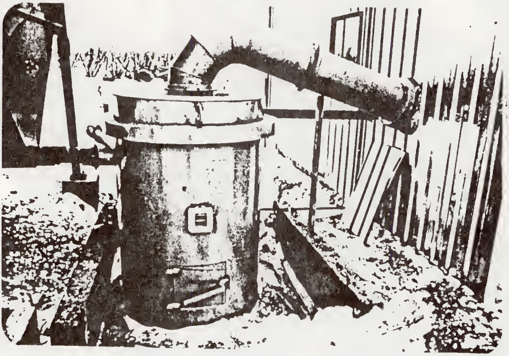
Testing of Alcohol Dehydrator

The dehydrator was tested by pumping 185 proof alcohol through the dehydrator at a flow rate of 10 gallons per minute. As the molecular sieve beads in the dehydrator column adsorbed the water in the alcohol, the temperature of the column gradually increased to 150 F , an indication that the beads were operating correctly. Approximately 200 gallons of alcohol was pumped through the column with the outlet proof measured to be 200 proof by a hydrometer.

To regenerate the molecular sieve beads after being saturated with water, the 4-way valve on the dehydrator pump was first positioned to drain the column. Then hot flue gases from the straw fired boiler were passed up the column on the outside of the pipes containing the molecular sieve beads until the temperature was 400 F after 6 hours. During the regeneration cycle, the vapors coming out of the column were condensed in a water cooled condenser. Approximately 25 gallons of 190 proof alcohol was condensed and pumped back to the alcohol tank and 20 gallons of water and lower proof alcohol was condensed and pumped back to the beer tank.

CHOPPED STRAW BIN [illegible]

TUB GRINDER [illegible]



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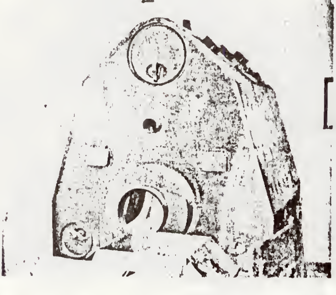
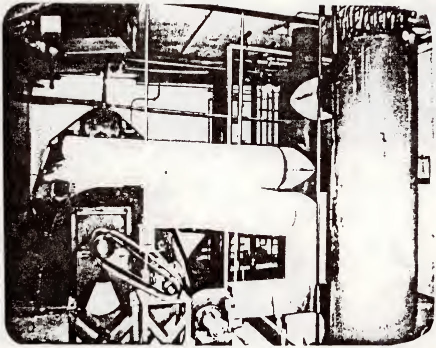


[illegible] BALER

[illegible] STACK



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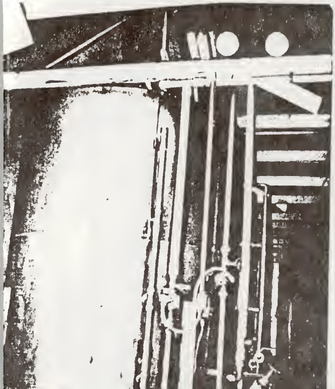
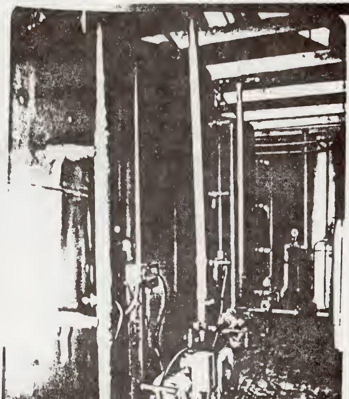
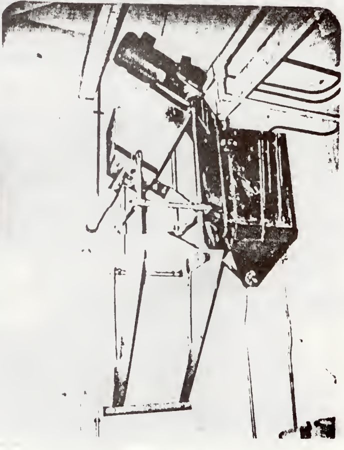


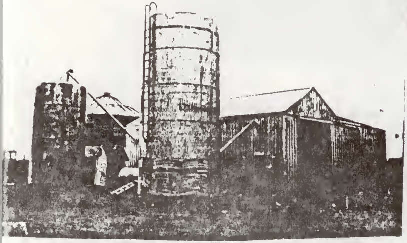
[illegible] FERMENTATION TANKS



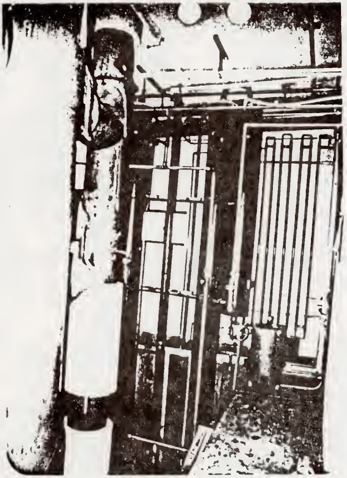
MIXING PUMP

SOLIDS SEPARATOR





[illegible] GRAIN
[illegible]



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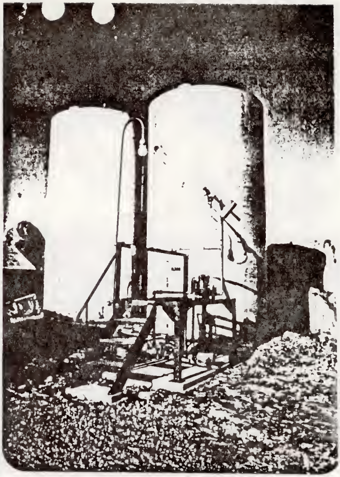

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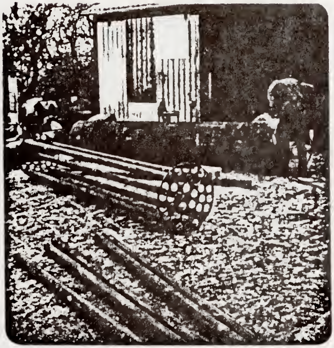

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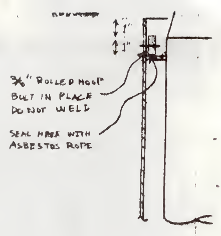
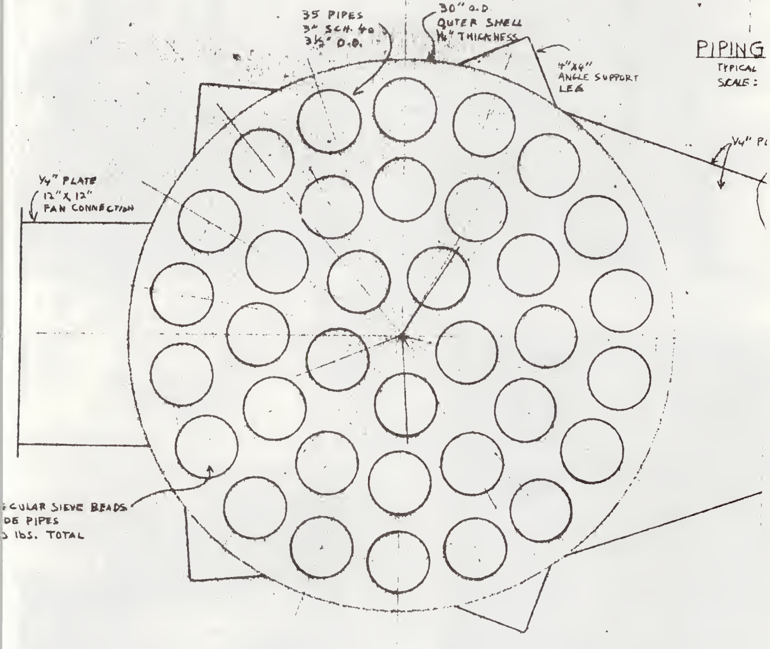
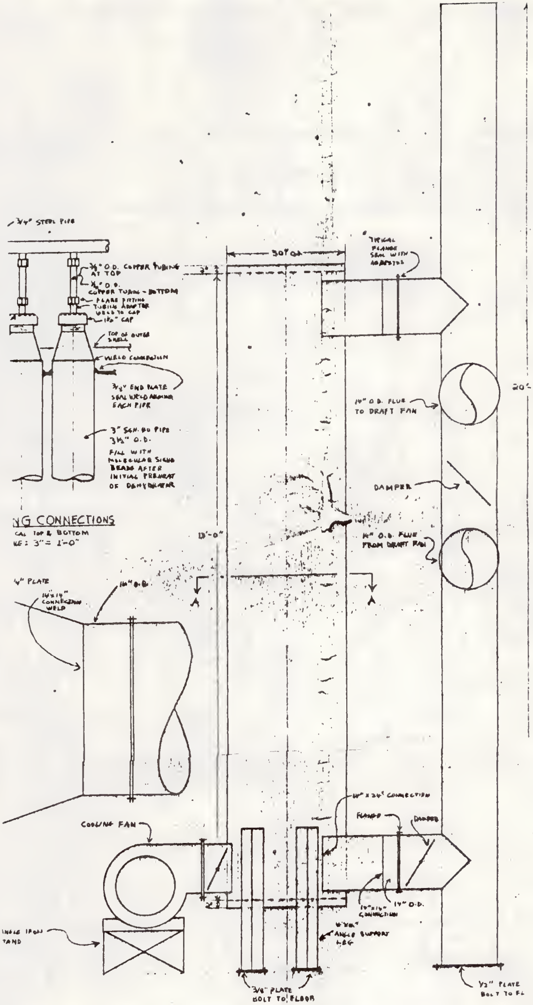

1"
1"
3/8" ROLLED HOOP BOLT IN PLACE DO NOT WELD
SEAL HERE WITH ASBESTOS ROPE

PIPING
TYPICAL
SCALE:

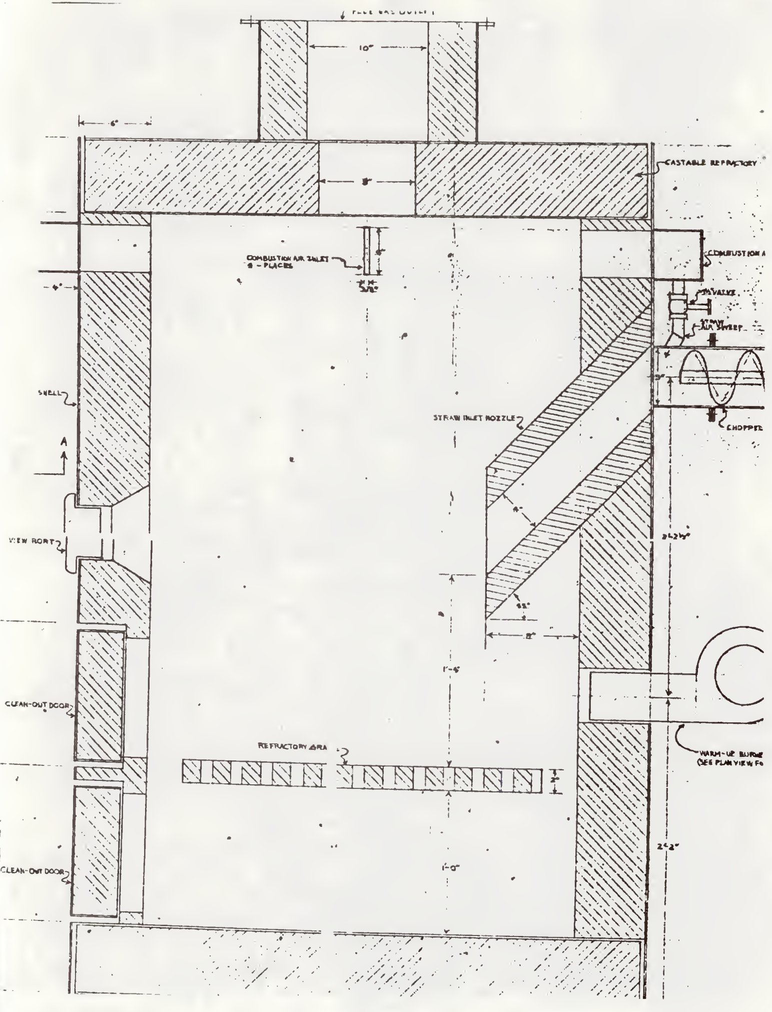

35 PIPES 3" SCH. 40 3½" O.D.
30" O.D. OUTER SHELL 1/4" THICKNESS
4"X4" ANGLE SUPPORT LEG
1/4" PL
1/4" PLATE 12"X12" FAN CONNECTION
CULAR SIEVE BEADS DE PIPES lbs. TOTAL
ANGLE IR STAND

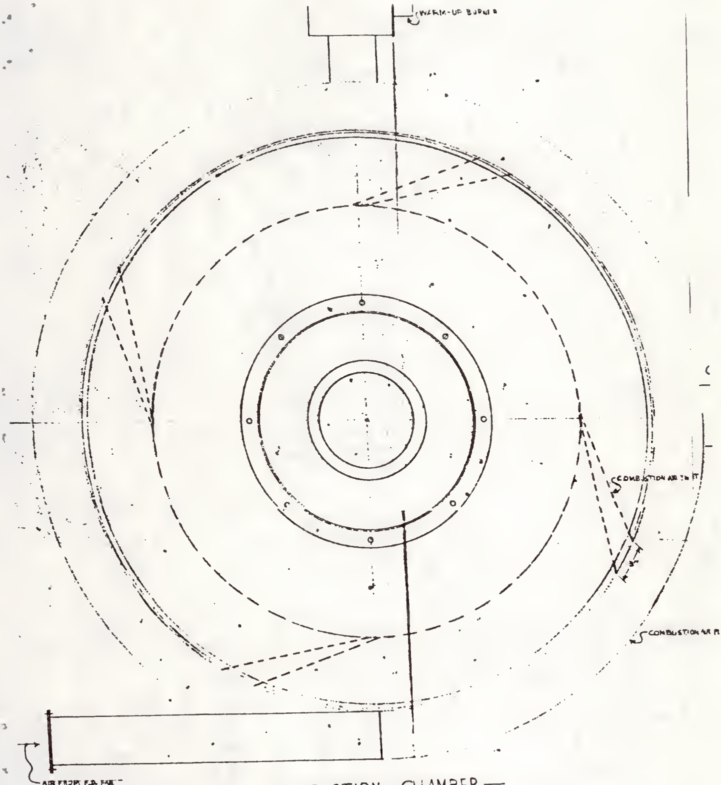
SECTION A-A

SCALE: 3" = 1'-0"

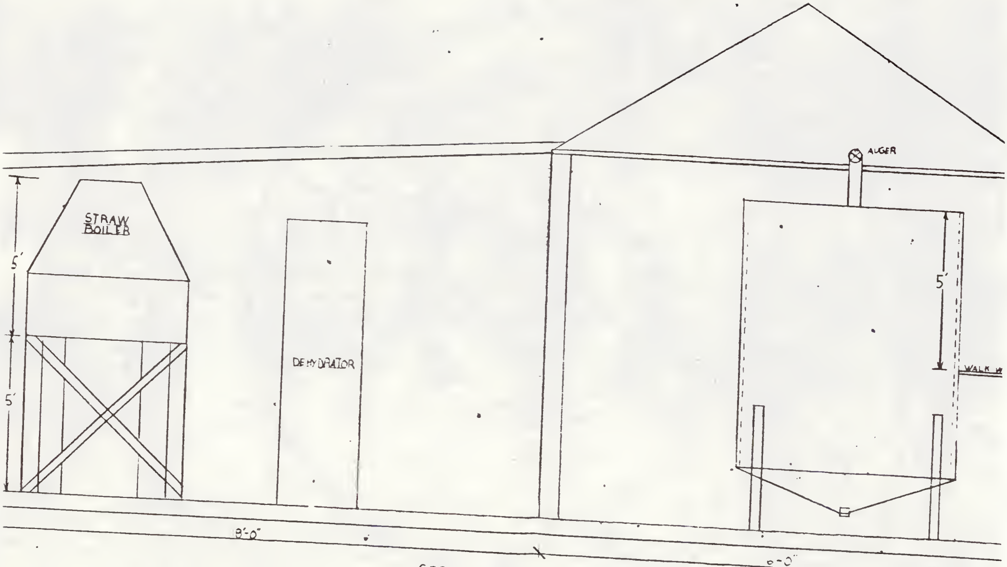


3/4" STEEL PIPE
3/8" O.D. COPPER TUBING AT TOP
1/4" O.D. COPPER TUBING - BOTTOM
FLARE FITTING
TUBING ADAPTER WELD TO CAP
1½" CAP
TOP OF OUTER SHELL
WELD CONNECTION
3/8" END PLATE SEAL WELD AROUND EACH PIPE
3" SCH. 80 PIPE 3½" O.D.
FILL WITH MOLECULAR SIEVE BEADS AFTER INITIAL PREHEAT OF DEHYDRATOR
NG CONNECTIONS
CAL TOP & BOTTOM
LE: 3" = 1'-0"
¼" PLATE
14"x14" CONNECTION WELD
14" O.D.
30" O.D.
3"
TYPICAL FLANGE SEAL WITH ASBESTOS
14" O.D. FLUE TO DRAFT FAN
20'-
DAMPER
14" O.D. FLUE FROM DRAFT FAN
13'-0"
A
A
COOLING FAN
14" x 24" CONNECTION
FLANGE
DAMPER
3"
10"x16" CONNECTION
14" O.D.
ANGLE IRON STAND
4"x4" ANGLE SUPPORT LEG
3/8" PLATE BOLT TO FLOOR
½" PLATE BOLT TO FL

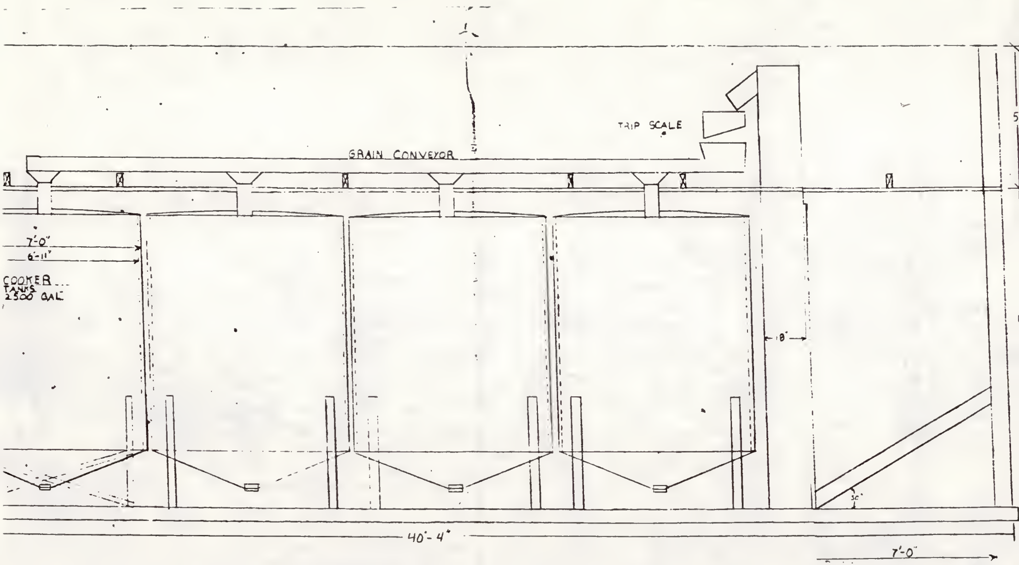

FLUE GAS OUTLET
10"
6"
8"
CASTABLE REFRACTORY
COMBUSTION AIR INLET
8 - PLACES
3/8"
COMBUSTION A
3/4" VALVE
STRAW AIR SWEEP
4"
3"
CHOPPER
STRAW INLET NOZZLE
4"
SHELL
A
VIEW PORT
4"
52°
8"
2'-2 1/2"
1'-6"
CLEAN-OUT DOOR
WARM-UP BURNE
(SEE PLAN VIEW FO
REFRACTORY GRID
2"
2'-2"
1'-0"
CLEAN-OUT DOOR



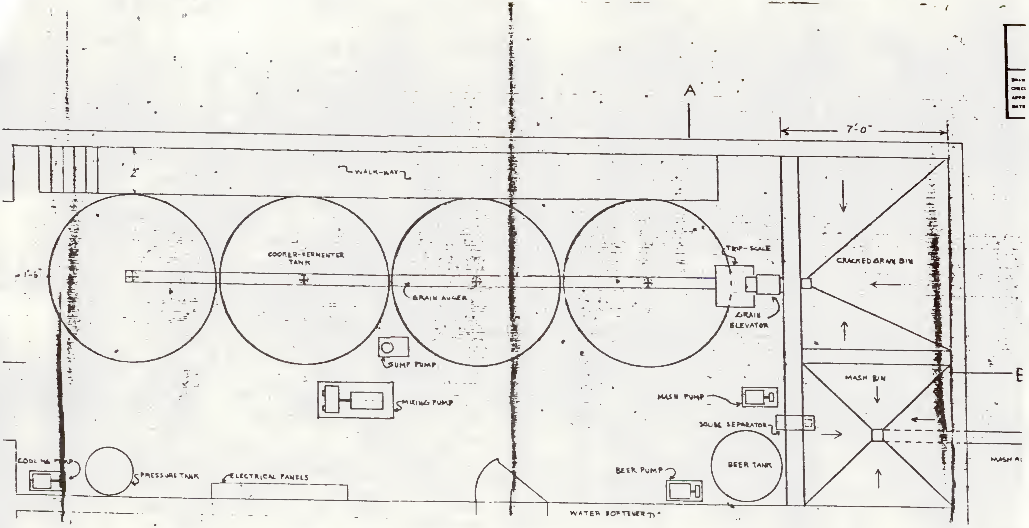
— STRAW FIRED COMBUSTION CHAMBER —

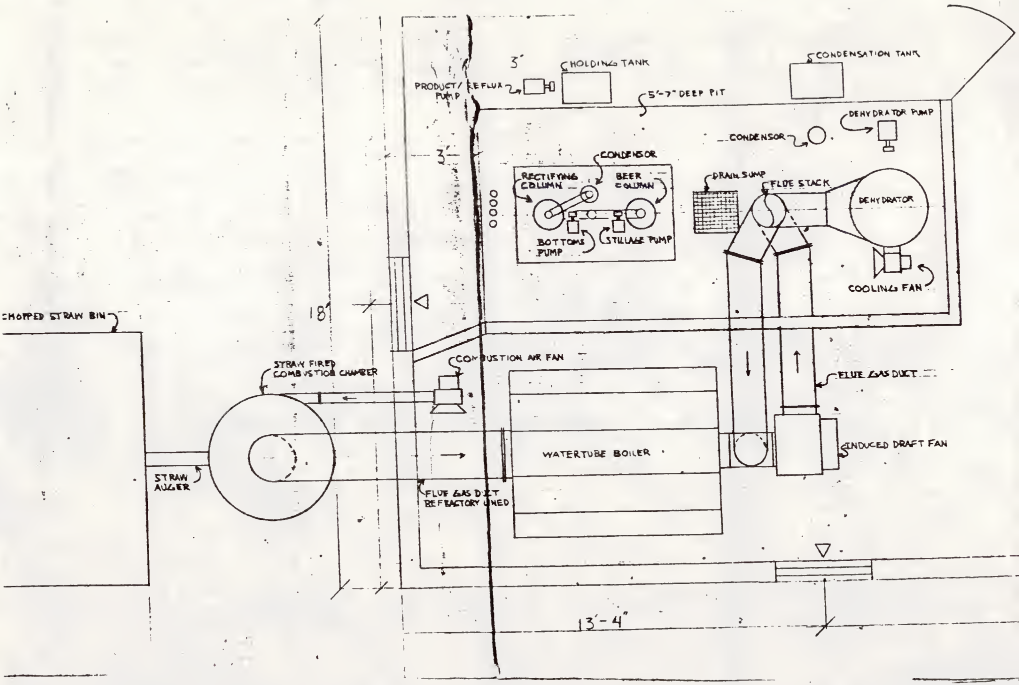


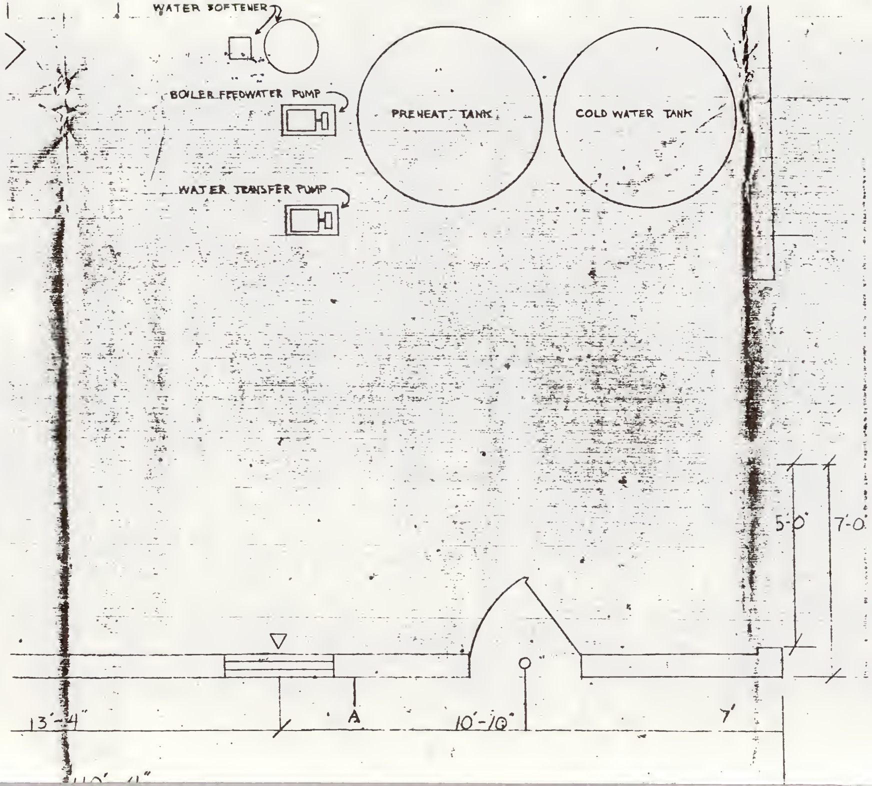
SECTION A-A


TRIP SCALE
GRAIN CONVEYOR
7'-0"
6'-11"
COOKER TANKS 2500 GAL
18"
50°
40'-4"
7'-0"
5

SECTION B-B


A
7'-0"
2"
WALK-WAY
1'-6"
COOKER-FERMENTER TANK
GRAIN AUGER
TRIP-SCALE
GRAIN ELEVATOR
CRACKED GRAIN BIN
SUMP PUMP
MIXING PUMP
MASH BIN
MASH PUMP
SOLIDS SEPARATOR
BEER TANK
BEER PUMP
COOLING PUMP
PRESSURE TANK
ELECTRICAL PANELS
WATER SOFTENER
MASH A
E
DRAW
CHEC
APPR
DATE


3'
HOLDING TANK
CONDENSATION TANK
PRODUCT/REFLUX PUMP
5'-7" DEEP PIT
DEHYDRATOR PUMP
CONDENSOR
3'
CONDENSOR
RECTIFYING COLUMN
BEER COLUMN
BOTTOMS PUMP
STILLAGE PUMP
DRAIN SUMP
FLUE STACK
DEHYDRATOR
COOLING FAN
18'
CHOPPED STRAW BIN
STRAW FIRED COMBUSTION CHAMBER
COMBUSTION AIR FAN
FLUE GAS DUCT
INDUCED DRAFT FAN
WATERTUBE BOILER
STRAW AUGER
FLUE GAS DUCT REFRACTORY LINED
13'-4"


WATER SOFTENER
BOILER FEEDWATER PUMP
PREHEAT TANK
COLD WATER TANK
WATER TRANSFER PUMP
5'-0"
7'-0"
A
13'-4"
10'-10"
7'

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